

WHAT IS CLAIMED AS NEW AND DESIRED TO BE SECURED BY LETTERS
PATENT OF THE UNITED STATES IS:

1. A method for monitoring current in a step start process, comprising:

5 connecting power to a load through current limiting devices for a step start interval of
time;

measuring current signals representing current flowing through said current limiting
devices;

sampling said current signals to obtain step start current sample values;

10 comparing said step start current sample values with a known acceptable pattern to
detect abnormal characteristics; and

disconnecting said power from said load if said abnormal characteristics are detected.

2. The method of Claim 1, further comprising:

obtaining voltage signals representing voltage applied to said current limiting devices;

generating timing signals from said voltage signals; and

performing said sampling of said current signals during sampling time intervals
determined by said timing signals to obtain said step start current sample values.

3. The method of Claim 2, further comprising:

performing the step of generating said timing signals from said voltage signals by
20 detecting zero voltage crossing.

4. The method of Claim 2, wherein the step of sampling of said current signals to
obtain said step start current sample values further comprises:

detecting peak levels of said current signals;

generating analog current sample values representing said peak levels of said current
25 signals;

storing said analog current sample values;

converting said analog current sample values to digital current sample values; and
employing said digital current sample values as said step start current sample values.

5. The method of Claim 4, wherein said current limiting devices are resistors.

6. The method of Claim 4, wherein said load comprises an electron tube.

7. The method of Claim 4, wherein said load comprises a dynamoelectric motor.

8. A method for determining a minimum cooling down time for current limiting
devices in a step start process, comprising:

measuring a rate of cooling of said current limiting devices;

connecting power to a load through said current limiting devices for a step start
interval of time;

measuring current signals representing current flowing through said current limiting
devices;

sampling said current signals during sampling time intervals to obtain step start
current sample values;

squaring said step start current sample values to give heat values related to heat
dissipated during each said sampling time interval;

summing said heat values for all said sampling time intervals during said step start
interval to give a total heat value related to total heat energy dissipated by said current
limiting devices during said step start interval; and

determining said minimum cooling down time for said current limiting devices,
dependent upon said total heat value and said rate of cooling.

9. The method of Claim 8, further comprising:

disabling reconnection of said power to said load after disconnection;

waiting for said minimum cooling down time; and

enabling said reconnection of said power to said load.

10. The method of Claim 9, further comprising:

obtaining voltage signals representing voltage applied to said current limiting devices;
generating timing signals from said voltage signals; and,
performing said sampling of said current signals during said sampling time intervals
determined by said timing signals to obtain said step start current sample values.

11. The method of Claim 10, further comprising:

performing the step of generating said timing signals from said voltage signals by
detecting zero voltage crossing.

12. The method of Claim 10, wherein the step of sampling said current signals to
obtain said step start current sample values further comprises:

detecting peak levels of said current signals;
generating analog current sample values representing said peak levels of said current
signals;
storing said analog current sample values;
converting said analog current sample values to digital current sample values; and
employing said digital current sample values as said step start current sample values.

13. The method of Claim 12, wherein said current limiting devices are resistors.

14. The method of Claim 12, wherein said load comprises an electron tube.

15. The method of Claim 12, wherein said load comprises a dynamoelectric motor.

16. A method for monitoring current, comprising:

connecting power to a load;
measuring current signals representing current supplied to said load;
obtaining voltage signals representing voltage applied to said load;
generating timing signals from said voltage signals;
sampling said current signals during sampling time intervals determined by said

timing signals to obtain operating current sample values; and

comparing said operating current sample values with a known acceptable pattern to detect abnormal characteristics.

17. The method of Claim 16, further comprising:

disconnecting said power from said load if said abnormal characteristics are detected.

18. The method of Claim 17, further comprising:

performing the step of generating said timing signals from said voltage signals by detecting zero voltage crossing.

19. The method of Claim 17, wherein the step of sampling said current signals to obtain said operating current sample values further comprises:

detecting peak levels of said current signals;

generating analog current sample values representing said peak levels of said current signals;

storing said analog current sample values;

converting said analog current sample values to digital current sample values; and

employing said digital current sample values as said operating current sample values.

20. The method of Claim 19, wherein said current limiting devices are resistors.

21. The method of Claim 19, wherein said load comprises an electron tube.

22. The method of Claim 19, wherein said load comprises a dynamoelectric motor.

23. An apparatus for monitoring current in a step start process, comprising:

means for connecting power to a load through current limiting devices for a step start interval of time;

means for measuring current signals representing current flowing through said current limiting devices;

means for sampling said current signals to obtain step start current sample values;

means for comparing said step start current sample values with a known acceptable pattern to detect abnormal characteristics; and

means for disconnecting said power from said load if said abnormal characteristics are detected.

24. The apparatus of Claim 23, further comprising:

means for obtaining voltage signals representing voltage applied to said current limiting devices;

means for generating timing signals from said voltage signals; and

means for performing said sampling of said current signals during sampling time intervals determined by said timing signals to obtain said step start current sample values.

25. The apparatus of Claim 24, wherein said means for generating said timing signals from said voltage signals comprises:

means for detecting zero voltage crossing.

26. The apparatus of Claim 24, wherein said means for sampling said current signals to obtain said step start current sample values further comprises:

means for detecting peak levels of said current signals;

means for generating analog current sample values representing said peak levels of said current signals;

means for storing said analog current sample values;

means for converting said analog current sample values to digital current sample values; and

means for employing said digital current sample values as said step start current sample values.

27. The apparatus of Claim 26, wherein said current limiting devices are resistors.

28. The apparatus of Claim 26, wherein said load comprises an electron tube.

29. The apparatus of Claim 26, wherein said load comprises a dynamoelectric motor.

30. An apparatus for determining a minimum cooling down time for current limiting devices in a step start process, comprising:

means for measuring a rate of cooling of said current limiting devices;

5 means for connecting power to a load through said current limiting devices for a step start interval of time;

means for measuring current signals representing current flowing through said current limiting devices;

10 means for sampling said current signals during sampling time intervals to obtain step start current sample values;

means for squaring said step start current sample values to give heat values related to heat dissipated during each said sampling time interval;

15 means for summing said heat values for all said sampling time intervals during said step start interval to give a total heat value related to total heat energy dissipated by said current limiting devices during said step start interval; and

means for determining said minimum cooling down time for said current limiting devices, dependent upon said total heat value and said rate of cooling.

31. The apparatus of Claim 30, further comprising:

means for disabling reconnection of said power to said load after disconnection;

20 means for delaying said reconnection for said minimum cooling down time; and

means for enabling said reconnection of said power to said load.

32. The apparatus of Claim 31, further comprising:

means for obtaining voltage signals representing voltage applied to said current limiting devices;

25 means for generating timing signals from said voltage signals; and,

means for performing said sampling of said current signals during said sampling time intervals determined by said timing signals to obtain said step start current sample values.

33. The apparatus of Claim 32, wherein said means for generating said timing signals from said voltage signals comprises:

means for detecting zero voltage crossing.

34. The apparatus of Claim 32, wherein said means for sampling said current signals to obtain said step start current sample values further comprises:

means for detecting peak levels of said current signals;

means for generating analog current sample values representing said peak levels of said current signals;

means for storing said analog current sample values;

means for converting said analog current sample values to digital current sample values; and

means for employing said digital current sample values as said step start current sample values.

35. The apparatus of Claim 34, wherein said current limiting devices are resistors.

36. The apparatus of Claim 34, wherein said load comprises an electron tube.

37. The apparatus of Claim 34, wherein said load comprises a dynamoelectric motor.

38. An apparatus for monitoring current, comprising:

means for connecting power to a load;

means for measuring current signals representing current supplied to said load;

means for obtaining voltage signals representing voltage applied to said load;

means for generating timing signals from said voltage signals;

means for sampling said current signals during sampling time intervals determined by said timing signals to obtain operating current sample values; and

means for comparing said operating current sample values with a known acceptable pattern to detect abnormal characteristics.

39. The apparatus of Claim 38, further comprising:

means for disconnecting said power from said load if said abnormal characteristics are detected.

40. The apparatus of Claim 39, wherein said means for generating said timing signals from said voltage signals comprises:

means for detecting zero voltage crossing.

41. The apparatus of Claim 39, wherein said means for sampling said current signals to obtain said operating current sample values further comprises:

means for detecting peak levels of said current signals;

means for generating analog current sample values representing said peak levels of said current signals;

means for storing said analog current sample values;

means for converting said analog current sample values to digital current sample values; and

means for employing said digital current sample values as said operating current sample values.

42. The apparatus of Claim 41, wherein said current limiting devices are resistors.

43. The apparatus of Claim 41, wherein said load comprises an electron tube.

44. The apparatus of Claim 41, wherein said load comprises a dynamoelectric motor.

45. A computer program product comprising a computer storage medium having a computer program code mechanism embedded in the computer storage medium for monitoring current in a step start process, the computer program code mechanism performing the steps of:

connecting power to a load through current limiting devices for a step start interval of time;

measuring current signals representing current flowing through said current limiting devices;

5 sampling said current signals to obtain step start current sample values;

comparing said step start current sample values with a known acceptable pattern to detect abnormal characteristics; and

disconnecting said power from said load if said abnormal characteristics are detected.

10 46. The computer program product of Claim 45, wherein the computer program code mechanism further performs the steps of:

obtaining voltage signals representing voltage applied to said current limiting devices;

generating timing signals from said voltage signals; and

performing said sampling of said current signals during sampling time intervals determined by said timing signals to obtain said step start current sample values.

15 47. The computer program product of Claim 46, wherein the step of generating said timing signals from said voltage signals further comprises:

detecting zero voltage crossing.

48. The computer program product of Claim 46, wherein the step of sampling of said current signals to obtain said step start current sample values further comprises:

20 detecting peak levels of said current signals;

generating analog current sample values representing said peak levels of said current signals;

storing said analog current sample values;

converting said analog current sample values to digital current sample values; and

25 employing said digital current sample values as said step start current sample values.

49. The computer program product of Claim 48, wherein said current limiting devices are resistors.

50. The computer program product of Claim 48, wherein said load comprises an electron tube.

51. The computer program product of Claim 48, wherein said load comprises a dynamoelectric motor.

52. A computer program product comprising a computer storage medium having a computer program code mechanism embedded in the computer storage medium for determining a minimum cooling down time for current limiting devices in a step start process, the computer program code mechanism performing the steps of:

measuring a rate of cooling of said current limiting devices;

connecting power to a load through said current limiting devices for a step start interval of time;

measuring current signals representing current flowing through said current limiting devices;

sampling said current signals during sampling time intervals to obtain step start current sample values;

squaring said step start current sample values to give heat values related to heat dissipated during each said sampling time interval;

summing said heat values for all said sampling time intervals during said step start interval to give a total heat value related to total heat energy dissipated by said current limiting devices during said step start interval; and

determining said minimum cooling down time for said current limiting devices, dependent upon said total heat value and said rate of cooling.

53. The computer program product of Claim 52, wherein the computer program code

mechanism further performs the steps of:

disabling reconnection of said power to said load after disconnection;

waiting for said minimum cooling down time; and

enabling said reconnection of said power to said load.

5 54. The computer program product of Claim 53, wherein the computer program code mechanism further performs the steps of:

obtaining voltage signals representing voltage applied to said current limiting devices;

generating timing signals from said voltage signals; and,

performing said sampling of said current signals during said sampling time intervals

10 determined by said timing signals to obtain said step start current sample values.

55. The computer program product of Claim 54, wherein the step of generating said timing signals from said voltage signals further comprises:

detecting zero voltage crossing.

56. The computer program product of Claim 54, wherein the step of sampling said current signals to obtain said step start current sample values further comprises:

detecting peak levels of said current signals;

generating analog current sample values representing said peak levels of said current signals;

storing said analog current sample values;

20 converting said analog current sample values to digital current sample values; and

employing said digital current sample values as said step start current sample values.

57. The computer program product of Claim 56, wherein said current limiting devices are resistors.

58. The computer program product of Claim 56, wherein said load comprises an
25 electron tube.

59. The computer program product of Claim 56, wherein said load comprises a dynamoelectric motor.

60. A computer program product comprising a computer storage medium having a computer program code mechanism embedded in the computer storage medium for

monitoring current, the computer program code mechanism performing the steps of:

connecting power to a load;

measuring current signals representing current supplied to said load;

obtaining voltage signals representing voltage applied to said load;

generating timing signals from said voltage signals;

sampling said current signals during sampling time intervals determined by said timing signals to obtain operating current sample values; and

comparing said operating current sample values with a known acceptable pattern to detect abnormal characteristics.

61. The computer program product of Claim 60, wherein the computer program code mechanism further performs the step of:

disconnecting said power from said load if said abnormal characteristics are detected.

62. The computer program product of Claim 61, wherein the step of generating said timing signals from said voltage signals further comprises:

detecting zero voltage crossing.

63. The computer program product of Claim 61, wherein the step of sampling said current signals to obtain said operating current sample values further comprises:

detecting peak levels of said current signals;

generating analog current sample values representing said peak levels of said current signals;

storing said analog current sample values;

converting said analog current sample values to digital current sample values; and
employing said digital current sample values as said operating current sample values.

64. The computer program product of Claim 63, wherein said current limiting devices
are resistors.

5 65. The computer program product of Claim 63, wherein said load comprises an
electron tube.

66. The computer program product of Claim 63, wherein said load comprises a
dynamoelectric motor.

67. An apparatus for monitoring current in a step start process, comprising:

10 a source of electrical power;

an electrical load;

a switching device selectively connecting said source of electrical power to said load;

a current limiting device;

15 a step start contactor selectively connecting said power to said load through said
current limiting device for a step start interval of time;

a current sensor measuring a current flowing through said current limiting device;

a current monitoring circuit comparing said current with a known acceptable pattern
and acting upon said switching device to disconnect said power from said load if said
abnormal characteristics are detected.

20 68. The apparatus of Claim 67, wherein said current monitoring circuit further
comprises:

a current sampling circuit sampling said current to obtain step start current sample
values;

a memory storing said known acceptable current pattern

25 a microprocessor comparing said step start current sample values with said known

acceptable current pattern to detect abnormal characteristics.

69. The apparatus of Claim 68, further comprising:

a timing circuit generating timing signals from voltage supplied by said source of electrical power;

5 said current sampling circuit performing said sampling of said current during sampling time intervals determined by said timing signals to obtain said step start current sample values.

70. The apparatus of Claim 69, wherein said timing circuit comprises:

a zero voltage crossing detector.

10 71. The apparatus of Claim 69, wherein said current sampling circuit further comprises:

a peak detector detecting peak levels of said current;

a sample and hold circuit generating and storing analog current sample values representing said peak levels of said current;

15 an analog to digital convertor converting said analog current sample values to digital current sample values.

72. The apparatus of Claim 71, wherein said current limiting devices is a resistor.

73. The apparatus of Claim 71, wherein said load comprises an electron tube.

74. The apparatus of Claim 71, wherein said load comprises a dynamoelectric motor.

20 75. The apparatus of Claim 67, wherein said current monitoring circuit comprises:
a digital signal processor.

76. The apparatus of Claim 75, wherein said current limiting devices is a resistor.

77. The apparatus of Claim 75, wherein said load comprises an electron tube.

78. The apparatus of Claim 75, wherein said load comprises a dynamoelectric motor.

25 79. An apparatus for determining a minimum cooling down time for a current

limiting device in a step start process, comprising:

a source of electrical power;

an electrical load;

a step start contactor selectively connecting said source of electrical power to said

load through said current limiting device for a step start interval of time;

a current sensor measuring current flowing through said current limiting device;

means for measuring a rate of cooling of said current limiting device;

a minimum cooling down time circuit, squaring and summing said step start current sample values to give a total heat value related to total heat energy dissipated by said current limiting device during said step start interval, and determining said minimum cooling down time for said current limiting device, dependent upon said total heat value and said rate of cooling.

80. The apparatus of Claim 79, wherein said minimum cooling down time circuit acts upon said switching device to prevent reconnection of said source of electrical power to said load for said minimum cooling down time after said load has been disconnected from said source of electrical power.

81. The apparatus of Claim 80, wherein said minimum cooling down time circuit further comprises:

a current sampling circuit sampling said current during sampling time intervals to

obtain step start current sample values;

a memory storing a program;

a microprocessor employing said stored program.

82. The apparatus of Claim 81, further comprising:

a timing circuit generating timing signals from voltage supplied by said source of

electrical power;

said current sampling circuit sampling said current during sampling time intervals determined by said timing signals to obtain current sample values.

83. The apparatus of Claim 82, wherein said timing circuit comprises:

a zero voltage crossing detector.

84. The apparatus of Claim 82, wherein said current sampling circuit further comprises:

a peak detector detecting peak levels of said current;

a sample and hold circuit generating and storing analog current sample values

representing said peak levels of said current;

an analog to digital convertor converting said analog current sample values to digital current sample values.

85. The apparatus of Claim 84, wherein said current limiting device is a resistor.

86. The apparatus of Claim 84, wherein said load comprises an electron tube.

87. The apparatus of Claim 84, wherein said load comprises a dynamoelectric motor.

88. The apparatus of Claim 79, wherein said minimum cooling down time circuit comprises:

a digital signal processor.

89. The apparatus of Claim 88, wherein said current limiting device is a resistor.

90. The apparatus of Claim 88, wherein said load comprises an electron tube.

91. The apparatus of Claim 88, wherein said load comprises a dynamoelectric motor.

92. An apparatus for monitoring current supplied to a load, comprising:

a source of electrical power;

a current sensor measuring current supplied to said load;

a current monitoring circuit generating timing signals from voltage supplied by said

source of electrical power, sampling said current during sampling time intervals determined

by said timing signals and comparing said operating current sample values with said known acceptable current pattern to detect abnormal characteristics.

93. The apparatus of Claim 92, further comprising:

a switching device selectively connecting said power to said load;

5 said current monitoring circuit acting upon said switching device to disconnect said power from said load if said abnormal characteristics are detected.

94. The apparatus of Claim 93, wherein said current monitoring circuit further comprises:

a timing circuit generating said timing signals;

10 a current sampling circuit sampling said current during said sampling time intervals;

a memory storing an acceptable current pattern; and

a microprocessor comparing said operating current sample values with said known acceptable current pattern.

95. The apparatus of Claim 94, wherein said timing circuit comprises:

15 a zero voltage crossing detector.

96. The apparatus of Claim 94, wherein said current sampling circuit further comprises:

a peak detector detecting peak levels of said current;

a sample and hold circuit generating and storing analog current sample values

20 representing said peak levels of said current; and

an analog to digital convertor converting said analog current sample values to digital current sample values.

97. The apparatus of Claim 96, wherein said current limiting device is a resistor.

98. The apparatus of Claim 96, wherein said load comprises an electron tube.

25 99. The apparatus of Claim 96, wherein said load comprises a dynamoelectric motor.

100. The apparatus of Claim 92, wherein said current monitoring circuit comprises a digital signal processor.

101. The apparatus of Claim 100, wherein said current limiting device is a resistor.

102. The apparatus of Claim 100, wherein said load comprises an electron tube.

5 103. The apparatus of Claim 100, wherein said load comprises a dynamoelectric motor.